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Previous nationally-representative research in Scotland found a j-shaped relationship between age and leisure sedentary time (ST): a decrease from young to middle-age, before rising steeply in older-age. This study investigated the effects of age and sex on weekday (including work) ST for all adults and stratified by work-status, and on weekend day ST. Differences in the relative contributions of component behaviours were also investigated. Responses from 14,367 adult (≥16 years) 2012-14 Scottish Health Survey participants were analysed using linear regressions. We found no j-shaped relationship between age and weekday ST. Instead, only 16-24 year olds reported lower levels than those over 75 years (6.6 (95% CI: 6.3-6.9) compared to 7.4 (95% CI: 7.2-7.6) hours/day; p<0001). The j-shape was only evident in the stratified analysis amongst women not in work, and for weekend day ST for all groups. For those in work, work ST accounted for 45% of weekday ST. Television/screen ST made up over half of leisure ST on weekdays and weekend days, regardless of sex, age, or work-status. These results challenge our understanding of how ST varies by age. Interventions to reduce ST should consider differences in the relative contributions of ST behaviours by age and work-status.

Keywords: sedentary; survey; sex; age; adults

Introduction

Sedentary time (ST) is defined as time spent in any waking activity which is undertaken in a sitting or reclined posture and has an energy expenditure of ≤1.5 metabolic equivalents of task (METs) (Sedentary Behaviour Research Network, 2012). There is growing evidence to suggest that high levels of ST (>7-10 hours/day) are associated with an increased risk of all-cause mortality, cardiovascular disease, type 2 diabetes, and some cancers amongst adults (Biswas et al., 2015; Chau et al., 2013; Pandey et al., 2016). These harmful effects can be attenuated by physical activity, but are only eliminated amongst those who undertake very high volumes (approximately 60-75 minutes of moderate intensity physical activity per day) (Ekelund et al., 2016). There is

also evidence to suggest that not all sedentary behaviours have equal health impacts: high levels of television (TV) viewing often show stronger negative associations than total ST with health outcomes such as type 2 diabetes and obesity (Hu, Li, Colditz, Willett, & Manson, 2003), and cancer (Schmid & Leitzmann, 2014). It is plausible that this is due to other concurrent unhealthy behaviours such as snacking on calorie dense foods (Jeffery & French, 1998; Meyer et al., 2008).

Currently, the UK physical activity guidelines recommend that people of all ages minimise the amount of time they spend being sedentary for extended periods (Department of Health, 2011). In Scotland, average daily ST is measured by the Scottish Health Survey (SHeS). Adult (≥16 years) participants are asked to report how much time they spend in sedentary behaviours, grouped into three categories: sitting at work, leisure TV/screen time, and any other leisure sedentary behaviours (such as eating a meal, reading, or listening to music). Participants are asked to respond based on their 'typical' working day (if applicable). For TV/screen ST and other leisure ST they are asked to report for an average week and weekend day (Bromley, Campbell-Jack, & Hinchliffe, 2015).

Although these data have been collected annually since 2012, limited summary statistics have been reported. The 2012 SHeS annual report published the mean hours of reported ST on weekdays and weekend days by age and sex, but only including leisure TV/screen ST and other leisure sedentary behaviours. Averages ranged between 4.6–7.6 hours/day, and there was a clear j-shaped trend with age for men and women: a decrease from young to middle-age, before rising steeply in older-age (Bromley, 2013). The Health Survey for England (HSE) found very similar results, using the same survey items (Scholes & Mindell, 2013).

The first research question is: do the relationships between ST and age and sex remain the same when work ST is included in the measure of weekday ST? Not including work ST could be distorting our understanding of the levels of ST amongst office workers in Scotland who, estimates suggest, spend 65-75% of their work time sitting down (Buckley et al., 2015). As the workplace is already a focus of many ST interventions (Shrestha et al., 2016) it is vital to include time spent sitting there in the national prevalence statistics.

The second research question is: how do the relative contributions of the categories of behaviours (sitting time at work, leisure TV/screen ST, and any other leisure ST) to weekday and weekend day ST vary by age and sex? This information is important to tailor and direct interventions to reduce ST. Given the potential differential health effects of the behaviours, further understanding of how they vary by age and sex for adults in Scotland is warranted.

Methods

Data source

We acquired the 2012-2013-2014 SHeS combined dataset from the UK data archive on 17th December 2015 (ScotCen Social Research, 2015). After weighting, the dataset is nationally representative of the population living in private households in Scotland from 2012 to 2014. Data are collected via an interviewer-led computer assisted interview. For more details see the SHeS Technical Report (Bromley et al., 2015).

Assessment of sedentary time

Adult participants (≥16 years) were asked to report the duration of sedentary behaviours

under three categories: (i) time spent sitting at work on a typical day, (ii) leisure time spent sitting watching TV or other screen devices on a typical weekday and weekend day, (iii) time spent in other leisure sedentary activities such as eating a meal, reading, or listening to music, on a typical weekday and weekend day (see Supplementary File 1 for the full questionnaire). Participants were instructed not to double-count the behaviours. We assumed that a typical work day was a weekday. Typical weekday ST was calculated as the sum of (i) and the weekday responses to (ii) and (iii). This relies on the assumption that a weekday is a working day. There are no official statistics for Scotland that support or discredit this assumption, however, the European Working Conditions Survey concluded that working a five-day week from Monday to Friday was still the norm for most Europeans (European Foundation for the Improvement of Living and Working Conditions, 2012). Typical weekend day ST was calculated as the sum of the weekend day responses to (ii) and (iii). Relative contributions of the categories of behaviours to weekday and weekend day ST were calculated for each individual as the proportion of time spent in each category out of the respective totals.

We undertook a comprehensive assessment of the validity and reliability evidence of the ST questions in the SHeS using the Edinburgh Framework as a guide (Kelly, Fitzsimons, & Baker, 2016). We found that limited high-quality evidence existed, but there were no major concerns (a summary of this work is included in Supplementary File 2). We acknowledge that the inherent limitation of self-reported data is the reliance on the participants' recall, however, this is currently the optimal way of collecting nationally-representative data on total and behaviour-specific ST for adults in Scotland (Dall et al., 2017).

Sample

There were 14,367 adult participants in the 2012-13-14 SHeS. Due to missing data in

one or more of the component variables, 98 cases were excluded from the weekday analyses and 77 from the weekend day analyses (<1% of total cases). In line with previous similar research (Bennie et al., 2013; Bennie et al., 2016), cases were excluded if their total exceeded 16 hours per day as these were considered to be outliers (136 cases for weekdays and 111 cases for weekend days; <1% of total cases). This left 14,133 cases in the weekday analyses and 14,179 cases in the weekend day analyses. These were weighted to make the sample nationally-representative of adults living in private households in Scotland (see Table 1).

Statistical analyses

We used multiple linear regressions to investigate the differences in weekday and weekend day ST by 10-year age band (from age 16), sex, and any interaction between these terms. We repeated these analyses stratified by work status (whether undertaken paid or self-employed work in four weeks prior to interview (57% of the sample), or not), and for the relative and absolute contributions of the categories of sedentary behaviours. Only one regression analysis was performed on the relative contributions of the categories of behaviours of weekday ST amongst non-workers and for weekend day ST. This was because the two categories were reciprocals. The reference categories were males and those over the age of 75 years as these were the groups that previous work had identified as sitting the most (Bromley, 2013). The analyses stratified by work status were an exception to this as there were not sufficient numbers in the oldest age group amongst those in employment to make meaningful comparisons. In this case we used 65-74 year olds as the reference age group.

There was strong evidence of digit preference for all the time variables as over 99% of responses ended in the digits 0 or 5; (Beaman, Vaske, Donnelly, & Manfredo, 1997; Kelly, 2013; Rietveld, 2001). Despite this, the underlying distributions of the

model residuals was approximately normal, with slight evidence of leptokurtis. Recommended strategies for dealing with these issues such as grouping observations into categories (Forthofer, Lee, & Hernandez, 2007), or performing transformations, did not alter the distribution pattern of the residuals and therefore the data were analysed as planned.

All analyses were performed in STATA version 14. Due to the stratified clustered sampling design (see Bromley et al. (2015)), we used Taylor-Series linearisation methods to estimate the variance. This was necessary because when a sample is clustered and/or stratified, the observations are not independent and identically distributed (an assumption of normal variance estimation techniques) (Heeringa, West, & Berglund, 2010). We have not used any cut-off to determine statistical significance but have presented the 95% confidence intervals (CI) and p-values (see Supplementary Tables), and have interpreted the results based on these factors and overall trends.

Results

Weekday sedentary time for men and women, by age group

Figure 1 and Table 1 show the mean reported typical weekday ST of adults in Scotland. There was strong evidence to suggest that, for men, the youngest age group (16-24 year olds) reported less ST than the oldest age group (over 75 years; 6.6 (6.3-6.9) compared to 7.4 (7.2-7.6) hours/day; $p<0.001$). There was some evidence to suggest the middle-age groups reported higher levels of ST than the oldest age group; 45-54 year olds reported 7.8 (7.6-7.8) compared to 7.4 (7.2-7.6) hours/day ($p=0.007$). However, we should be cautious not to over-interpret a 0.4 hour (24-minute) difference. For women,

there was strong evidence to suggest that the over 75s reported more ST than all other age groups (ranging between 6.6-6.9 (6.4-7.1) hours/day for 16-74 year olds compared to 7.4 (7.2-7.6) hours/day for the over 75s. We reached this conclusion as there was no evidence for a main effect of sex, but the p-values and confidence intervals suggested a main effect for 16-24 year olds and interaction effects between ages of 25 and 74. There was no difference in the reported weekday ST of men and women over the age of 75 years, but the interaction effect p-values suggest that women reported less ST than men between the ages of 25 and 74 (all $p<0.05$). See Supplementary Table 1 for regression results.

Insert Figure 1 and Table 1

Weekday sedentary time, stratified by work status

Figure 2 and Table 1 show the mean reported weekday ST of adults in Scotland, stratified by work status. For those in work (Figure 2A), the trends were similar to those for all adults, except that there was no evidence of any differences between the sexes. The youngest age group (16-24 year olds) were the only age group where there was evidence to suggest lower levels of reported ST compared to 65-74 year olds (6.8 (6.4-7.2) for men and women compared to 7.3-7.7 (6.7-8.2) hours/day; $p=0.003$). For those not in work (Figure 2B), there were clear differences by sex (relevant interaction effect p-values between ages of 25-65 years all ≤ 0.001). For men, again, it was only the 16-24 year olds where there was strong evidence to suggest lower levels of reported ST compared those over 75 years (6.3 (5.9-6.6) hours/day compared to 7.4 hours/day; $p<0.001$). However, for women, a j-shaped pattern was evident where those aged 25-44 years reported the lowest levels of ST (5.2-5.4 (4.9- 5.6) hours/day), but the highest levels of reported ST were amongst those over the age of 65 (6.7-7.4 (6.5-7.6) hours/day). See Supplementary Table 1 for regression results.

***Insert Figure 2 ***

Weekend day sedentary time

Figure 3 and Table 2 show that the association between reported weekend day ST and age group followed a j-shaped pattern for both sexes. Those aged 25 to 54 reported the lowest levels of weekend day ST (5.2-5.7 (5.0-5.9) hours/day). There was strong evidence to suggest that those over the age of 75 reported the most ST (7.3-7.4 (7.1-7.7) hours/day compared to 5.2-6.9 (5.0-7.1) hours/day for 16-65 year olds; all $p \leq 0.001$). See Supplementary Table 2 for regression results.

Insert Figure 3 and Table 2

Relative contributions of the categories of behaviours of weekday sedentary time

Figure 4 shows the mean relative contributions of the categories of behaviours to weekday ST, stratified by work status (see Supplementary Tables 3 and 4 for 95% CIs and regression results). For those that worked (Figure 4A), the relative contribution of sitting time at work was highest for both sexes between the ages of 25 to 64 (35-45% (33-47%) compared to 33.6% (30-37%) for men and 31% (26-36%) for women aged 65-74 years; all $p<0.01$). For those aged 16 to 74 years, leisure TV/screen ST showed the converse relationship. The highest contributions were seen amongst 16-24 year olds (50% (47-54%) for men and 45% (42-47%) for women). Other leisure ST was relatively constant between the ages of 16-74, ranging between 19 and 30% (18-32%).

Amongst those not in work (Figure 4B), the lowest contribution of leisure TV/screen ST (57-58% (55-59%)) and the highest contribution of other leisure ST (42-43% (41-45%)) was evident in those over the age of 75 ($p<0.001$ compared to all other age groups). For men, there was a gradual decline with age of the relative contribution

of leisure TV/screen ST, whilst for females there was some evidence of a peak in middle-age.

Relative contributions of weekend day sedentary time

Figure 5 shows the mean relative contributions of the categories of behaviours of weekend day ST (see Supplementary Table 3 and 4 for 95% CIs and regression results). Men over 75 years spent the lowest proportion of their weekend day ST watching TV or other screens compared to all other age groups (56% (54-58%) compared to 61-65% (60-68%) for 16-74 year olds; all $p<0.001$). This trend was not apparent amongst women where the division between leisure TV/screen ST and other leisure ST was more consistent between the age groups (ranging between 56-60% (55-62%); interaction effects for age groups between 16-65 years all $p<0.05$). This interaction effect could also be interpreted as indicating lower relative contributions of leisure TV/screen ST to weekend day ST for women compared with men, except in the oldest two age groups.

insert Figure 5

Discussion

The main finding from this paper is that including work ST in the estimates for weekday ST changes our understanding of how ST varies by age and sex for adults in Scotland. Without its inclusion, we see a j-shaped curve with the oldest age groups being most sedentary, and middle-aged adults the least. Our results indicate that this is only the case for women who do not work; all others demonstrate a different relationship between age group and weekday ST.

We have also found that, for those in work, up to 45% of weekday ST is accumulated at work. Leisure TV/screen ST made up over half of leisure ST for all age groups, both sexes, those in and out of employment, on weekdays and weekend days.

Weekday sedentary time including sitting time at work

The previous analyses of SHeS and HSE data have led to the assumption that older adults are the most sedentary age group within the UK (British Heart Foundation, 2014). Our results challenge that perception and stress the need to analyse the data on ST at work from UK national surveys. Without these analyses the potential health risk associated with ST is being underestimated for the working population. Our results also suggest that we need interventions to tackle high levels of ST in early and middle-age where patterns may develop, and that the workplace could be an appropriate place to target.

Our results are supported by some international multi-country studies that have also failed to show an increase in ST with age (Bauman et al., 2011; Bennie et al., 2013; Loyen, van der Ploeg, Bauman, Brug, & Lakerveld, 2016). This could be due to the method: all of these studies used a single item to ask about sitting time on a 'usual' day, although two of them specified weekday (Bauman et al., 2011; Bennie et al., 2013). Contrary to the present results, however, two of these reported the highest levels of ST amongst young adults (Bauman et al., 2011; Loyen, van der Ploeg, et al., 2016). It is possible that these mixed results could be explained by variations in the reference group. Our study chose to use the oldest age group, while others choose the youngest (Bennie et al., 2013), second youngest (Loyen, van der Ploeg, et al., 2016), or middle aged adults (Bauman et al., 2011). As this group drives all the comparisons, it is particularly important that this group have a sufficient sample size to enable differences to be detected, and are representative of their target population. In the present study, the older adult sample in the SHeS should be representative of those living in private households. However, this does not include those in medical or long-term care

establishments who may be more sedentary than respondents to the survey (Bromley et al., 2015).

We also found that, amongst adults that do not work, the relationship between age group and reported weekday ST was different for men and women. We speculate that the difference between middle aged men and women could be due to different reasons for not being at work: women may be more likely to be involved in childcare, which may involve lower levels of ST, whilst men may be more likely to be unable to work for health reasons, which may result higher levels of ST. These speculations are tentatively supported by Eurostat data for the United Kingdom: in 2013, 5% of men compared to 29% of women stated their main reason for not seeking employment was "looking after children or incapacitated adults", while 31% of men and 18% of women gave "own illness or disability" as their answer (Eurostat, 2016). If this sex difference is confirmed in other datasets using other populations and other measurement methods, then further research should investigate the potential reasons for these differences.

In the present study, the average reported ST for men and women ranged between 6.6-7.8 hours on weekdays and 5.2-7.4 hours on weekend days for the different age groups. These figures are slightly higher than some estimates from international studies using self-report questionnaires. The 2013 Eurobarometer survey asked over 24,000 inhabitants (≥15 years) of EU member states a single-item question on sitting. The whole sample mean was 4.9 hours, and the Great Britain sub-sample mean was 5.0 hours (Milton, Gale, Stamatakis, & Bauman, 2015). A recent review of population-level estimates for daily ST in European countries found the averages reported ranged between 2.5 hours/day to 10.3 hours/day, and UK studies had the largest variation of any nation (Loyen, Verloigne, et al., 2016). The large variation may be attributable to the variety of self-report and device-based measurement methods used, and the statistics

reported (medians and means). These results strengthen the case for further work is to find a common solution to measuring ST at a population-level (Dall et al., 2017). This will help us to fully understand the potential health-burden that it is placing on our society.

Behaviour-specific sedentary time

Our results show that for those that work, work ST makes up between one-quarter to nearly half of weekday ST. This justifies its inclusion in prevalence estimates. However, it is unclear why these proportions are lower than usual ranges reported in the literature (Clemes, O'Connell, & Edwardson, 2014; Clemes, Patel, Mahon, & Griffiths, 2014; Kazi, Duncan, Clemes, & Haslam, 2014; Ryan, Dall, Granat, & Grant, 2011), particularly, as described above, when the overall ST estimates are fractionally higher than other studies. We cannot rule out that that it is due to differences in measurement methods and/or contexts. The studies cited above use a variety of methods (objective, subjective, and a combination), and so it is possible that the context of data collection (e.g. in a wider health survey, or a specific study on sitting time at work) affected the reporting of domain-specific ST.

Like others, we found that leisure TV/screen ST was a greater contributor to leisure ST than other behaviours such as reading or eating (Clemes et al., 2015; Kazi et al., 2014). This applied to all adults, although was evident to the greatest extent amongst the 16-24 year olds. The cross-sectional nature of these data prevents us from making judgements as to whether this is a societal change that will continue as the current 16-24 year olds age, or whether it is a feature of that age group. It is nonetheless concerning given the potentially greater deleterious effects on health that TV viewing has compared to other sedentary behaviours (Ekelund et al., 2016).

We did not find substantial differences by sex in the relative contributions of the categories of behaviours. This is in contrast to the findings of Proper, Cerin, Brown, and Owen (2007). This may be due to the fact they looked at differences in individual activities rather than categories of behaviours in a sample of working-age Australian adults.

Implications for policy and practice

Based on these results, we would recommend that policy-makers in Scotland address the levels of ST amongst the adult population. The average weekday ST reported by the men and women in the different age groups ranged between 6.6 and 7.8 hours/day (95% CI 6.3-8.0). This implies that a large proportion of the population are at an increased risk of all-cause mortality, cardiovascular disease, type 2 diabetes, and some cancers amongst adults (Biswas et al., 2015; Chau et al., 2013; Pandey et al., 2016). A first step would be the addition of an appropriate indicator to the existing framework for monitoring physical activity levels in Scotland: the 'Active Scotland Outcomes Framework' (The Scottish Government, 2014).

Our results suggest that a key target group for intervention are early-to-middle aged adults who are in employment. They reported some of the highest weekday ST levels (group averages over 7 hours per day), close to half of which was accumulated at work. A recent review by Shrestha et al. (2016) found tentative evidence to suggest sit-to-stand desks could reduce work ST, at least in the short term. There was limited high quality evidence for other intervention types and so we support their call for more well-designed studies in this area. Regardless of sex or employment status, adults in Scotland accumulated more of their leisure ST through TV/screen time than other leisure-time sedentary behaviours. Wu, Sun, He, and Jiang (2016) found that interventions involving

health promotion or counselling rather than automated monitoring of screen time were most effective. This suggests interventions could be targeted at reducing TV/screen time, however, national surveillance in Scotland should decide whether the current level of behaviour-specific detail is appropriate to inform such interventions.

The challenge for researchers and policy-makers together, is to interpret the constantly evolving evidence that currently implies an interaction between levels of physical activity and ST on health outcomes (Ekelund et al., 2015), into clear public health messages. It may be, as Buckley et al. (2015) suggest, that encouraging people to "simply get standing and moving more frequently" could be the "first behavioural step" towards a healthier lifestyle as it is potentially more achievable than the aerobic physical activity guidelines (Department of Health, 2011).

Strengths and limitations

This paper is the first to use nationally representative data to show the differences by age and sex in the reported ST amongst adults in Scotland. In England, the HSE uses the same questions and method for deriving estimates for ST as the SHeS (Craig & Mindell, 2013), and the levels of ST are similar between the nations (Scholes & Mindell, 2013). Therefore, one would expect similar results if one repeated this analyses on the HSE data.

There are some limitations to this study and it is important to consider what effect they may have on the interpretation of the results.

Firstly, the data are self-reported and are therefore prone to error (random and systematic) in the recall process (Atkin et al., 2012). Some but not all studies have found that self-reported methods often produce lower estimates of ST compared to

objective measures (Healy et al., 2011). This would only strengthen the case for addressing the issue of high ST amongst adults in Scotland. However, it is important to remember thatself-report is the only realistic method of measurement for population-level surveillance in Scotland at present, and has the benefit of providing behaviour-level information (Dall et al., 2017).

Secondly, participants may not report some ST because they are carrying out activities that are not explicitly prompted. For example, time spent in motorised transport is not explicitly mentioned in the questions, nor is time spent sitting at school or university. The latter may particularly affect the youngest age group and is a potential explanation for their lower levels of reported ST.

Conclusion

In this paper, we have shown that the relationship between weekday ST and age and sex differs from our current understanding when ST at work is included in the measure. Our results challenge the conventional understanding that older adults in Scotland report the highest levels of ST, as the majority of middle-aged adults reported similar levels to older adults. In light of these results, we suggest changing the way national prevalence estimates are calculated for Scotland and England, so that they include ST at work. We have also shown the division of ST in three categories of behaviours. Based on these results, we recommend that ST at work amongst early-to-middle aged adults and leisure TV/screen time for all adults are considered as targets for interventions to reduce ST.

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Table 1. The mean (and 95% confidence intervals) for total and for the categories of behaviours of weekday sedentary time, for all adults and stratified by work status.

Table 2. The mean (and 95% confidence intervals) for total and for the categories of behaviours of weekend day sedentary time, for all adults and stratified by work status.

Figure 1. Weekday sedentary time for adults in Scotland, by age group and sex.
Figure 1 caption. Error bars represent the 95% confidence interval.

Figure 2. Weekday sedentary time for adults in Scotland, by age group and sex, stratified by work status.
Figure 2 caption. A: Those in work in the four weeks prior to interview. B: Those not in work in the four weeks prior to interview. Error bars represent the 95% confidence interval.

Figure 3. Weekend day sedentary time for adults in Scotland, by age group and sex.
Figure 3 caption. Error bars represent the 95% confidence interval.

Figure 4. The relative contributions of the categories of behaviours to weekday sedentary time for adults in Scotland, by age group and sex, stratified by work status.
Figure 4 caption. A: Those in work in the four weeks prior to interview. B: Those not in work in the four weeks prior to interview.

Figure 5. The relative contributions of the categories of behaviours to weekend day sedentary time for adults in Scotland, by age group and sex.

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Abbreviations:

ST – Sedentary time

MET – Metabolic equivalent of task

TV- Television

SHeS – Scottish Health Survey

HSE – Health Survey for England

CI – Confidence interval

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Geolocation statement: This study was conducted in at the University of Edinburgh, Scotland, UK.

Supplementary online material: Supplementary File 1 contains the relevant items from the SHeS questionnaire, Supplementary File 2 is a summary of our unpublished analysis into the validity and reliability of these items, Supplementary Tables contains additional analysis output. The dataset analysed during the current study is available in the UK data archive repository, SN 7594 http://dx.doi.org/10.5255/UKDA-SN-7594-1.